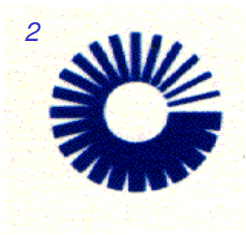


A HISTORY OF ICE PROTECTION SYSTEM DEVELOPMENT AT SIKORSKY AIRCRAFT

PAPER 2003-01-2092

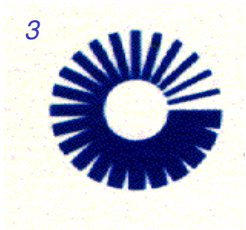
ROBERT J. FLEMMING
SIKORSKY AIRCRAFT CORPORATION
17 JUNE 2003

FAA Inflight Icing/Ground Deicing International Conference & Exhibition
Chicago, Illinois 16-20 June 2003

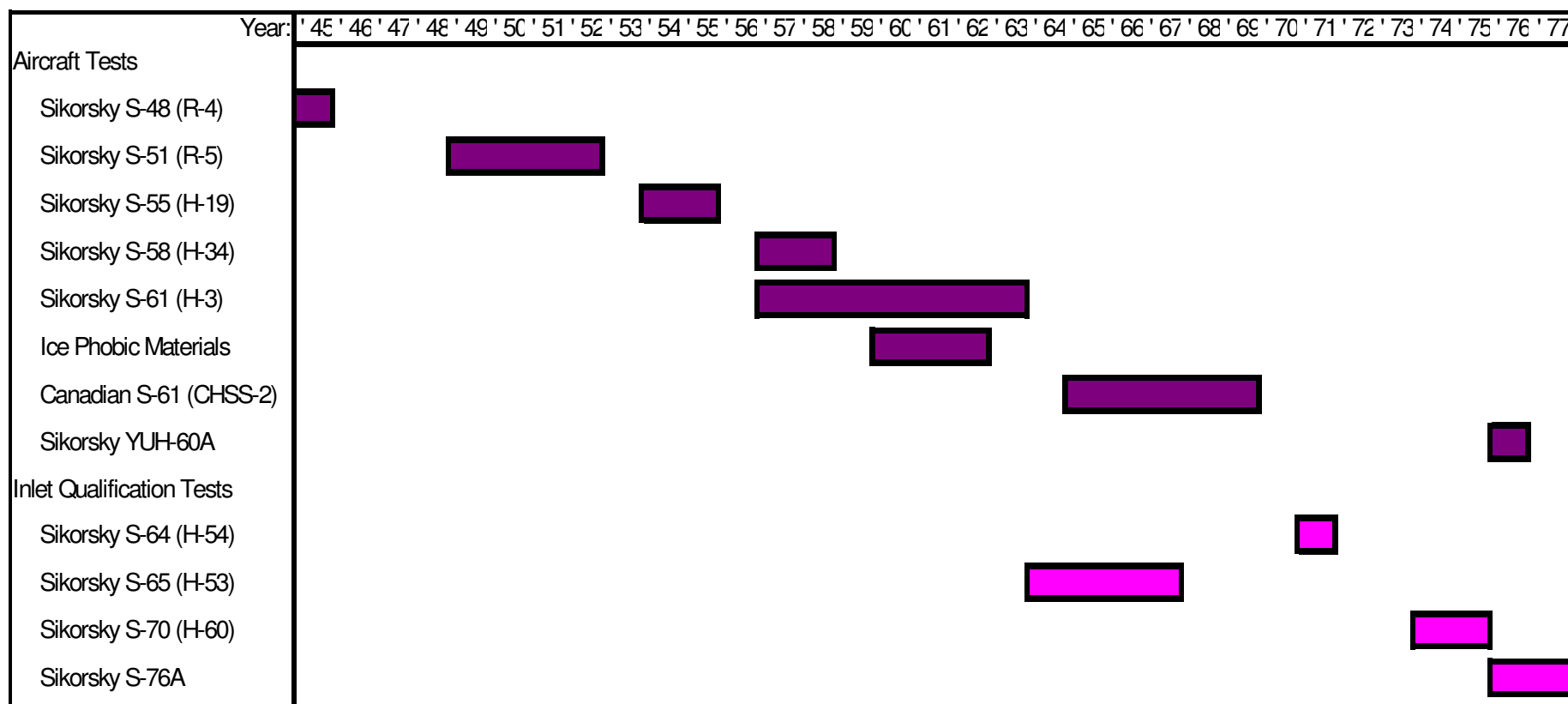


CONTENT OF PRESENTATION

- Early Sikorsky icing tests
 - Emphasis on full-scale aircraft testing
- Last twenty-seven years of icing tests
 - Full-scale inlet tests in NASA IRT
 - Full-scale aircraft testing
 - Natural icing, artificial icing, simulated ice
 - Code development and use
 - Scale model testing



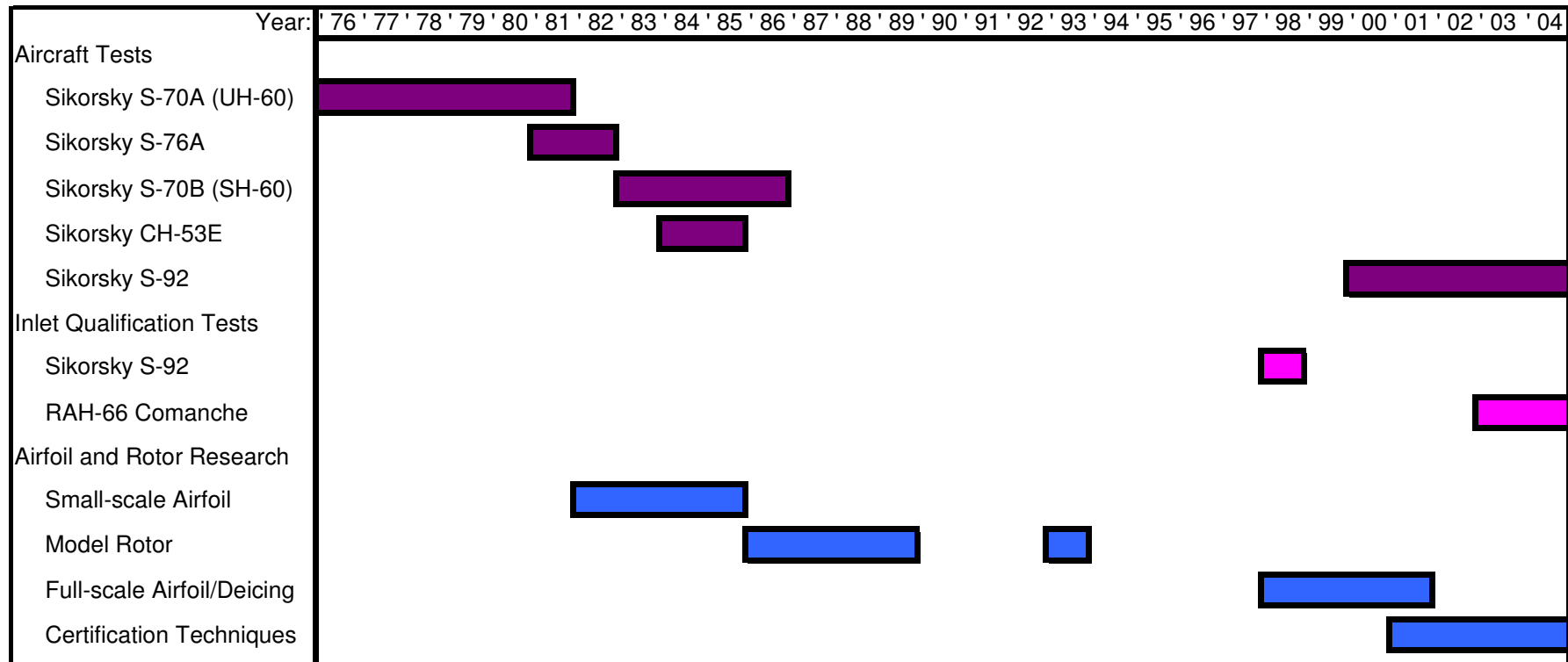
EARLY FULL-SCALE ICING TESTS



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SIKORSKY ICING TESTS PLANNED OR CONDUCTED DURING THE PAST TWENTY-FIVE YEARS



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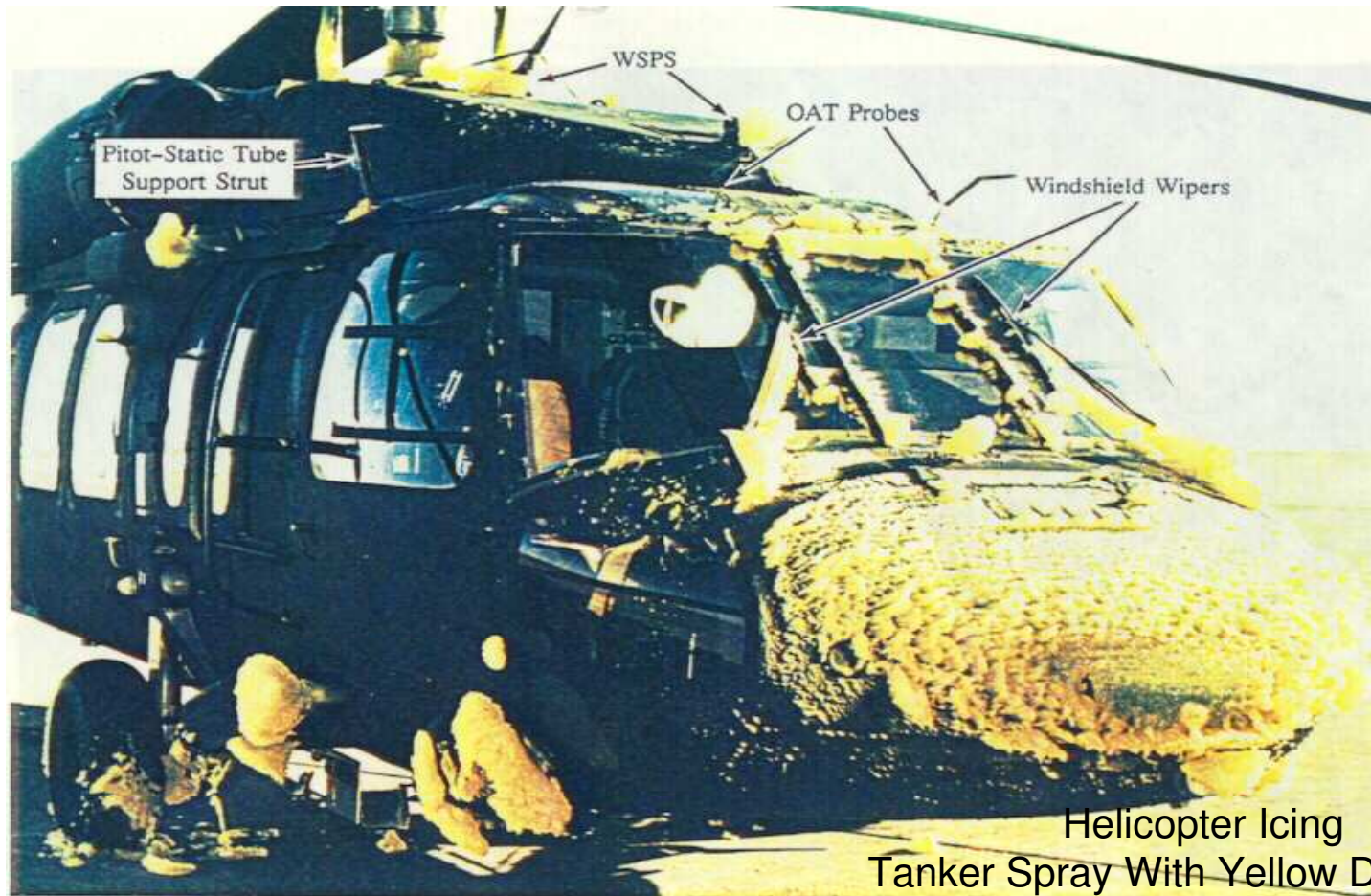
BLACK HAWK ICE PROTECTION SYSTEM

- The H-60 helicopter is qualified for flight in icing conditions.
- Most H-60 aircraft produced are delivered with full ice protection systems.
 - About 2450 ice protection systems delivered.
- H-60 air data system and windshield ice protection system are anti-icing systems.
- BLACK HAWK engine inlet is anti-iced using engine bleed air.
- Rotors deiced using electrothermal heater elements, controlled using temperature and LWC measurements.



BLACK HAWK AFTER AN ICING FLIGHT

DULUTH, MINNESOTA, USA

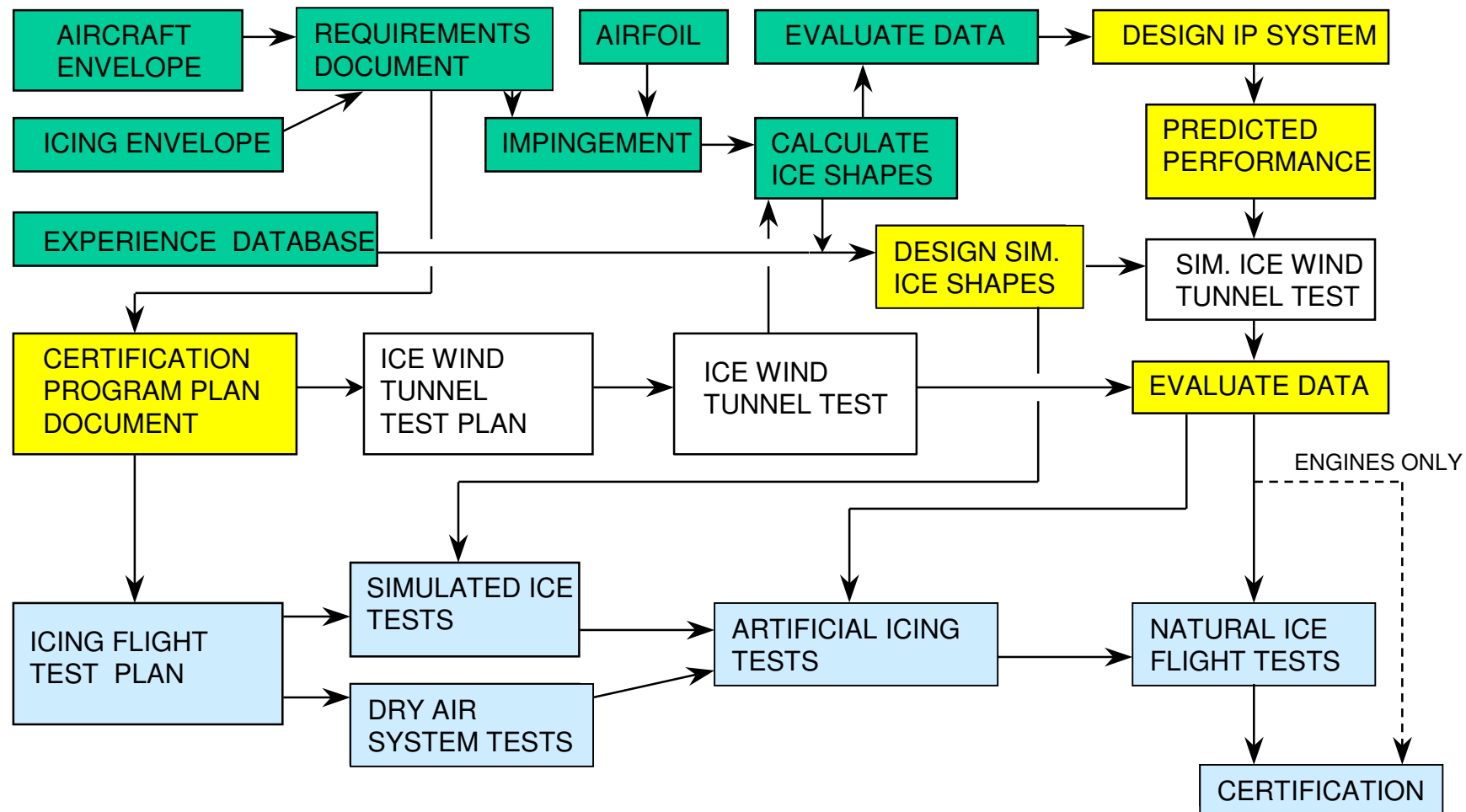


Helicopter Icing
Tanker Spray With Yellow Dye

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HELICOPTER ICING CERTIFICATION PROCESS





S-92 INLET
MODEL IN THE
NASA GLENN
ICING
RESEARCH
TUNNEL (VIEW
ROTATED 90
DEGREES)

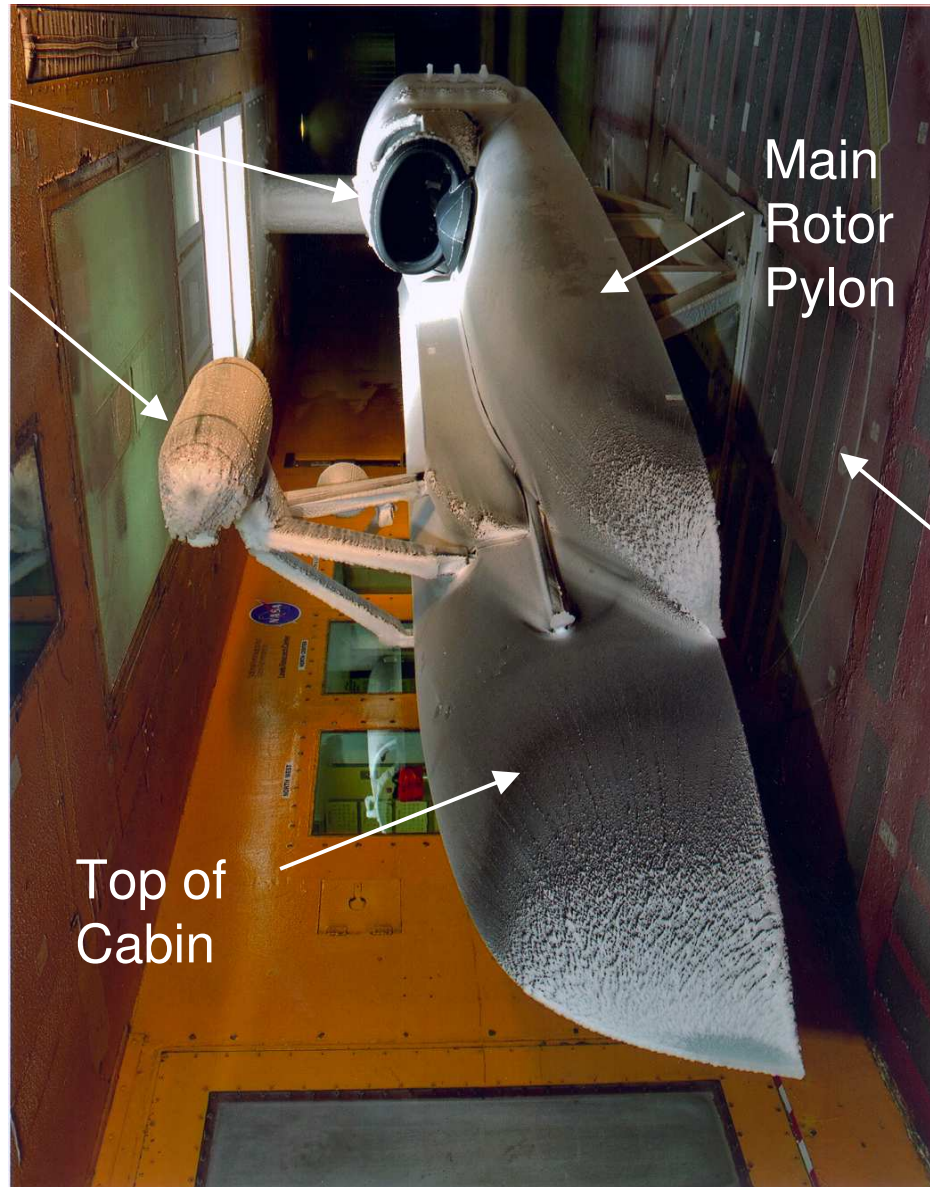
Engine
Inlet

Rescue
Hoist

Main
Rotor
Pylon

Floor
of
Tunnel

Top of
Cabin



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S-92A ROTOR ICE PROTECTION SYSTEM

- Ice detector/icing rate system - a primary system
- Main rotor woven wire electrothermal heaters
 - Deiced by blade pairs with 4 zones per blade
 - Operation governed by icing severity (LWC) and OAT
- Tail rotor electrothermal heater elements for deicing
 - Elements operate together
- System includes a two redundant controllers, a main rotor distributor, a main rotor slip ring, and a tail rotor slip ring



S-92A AIRFOIL MODEL INSTALLED IN THE NASA GLENN ICING RESEARCH TUNNEL

Sikorsky
SC2110 Airfoil

Wake traverse



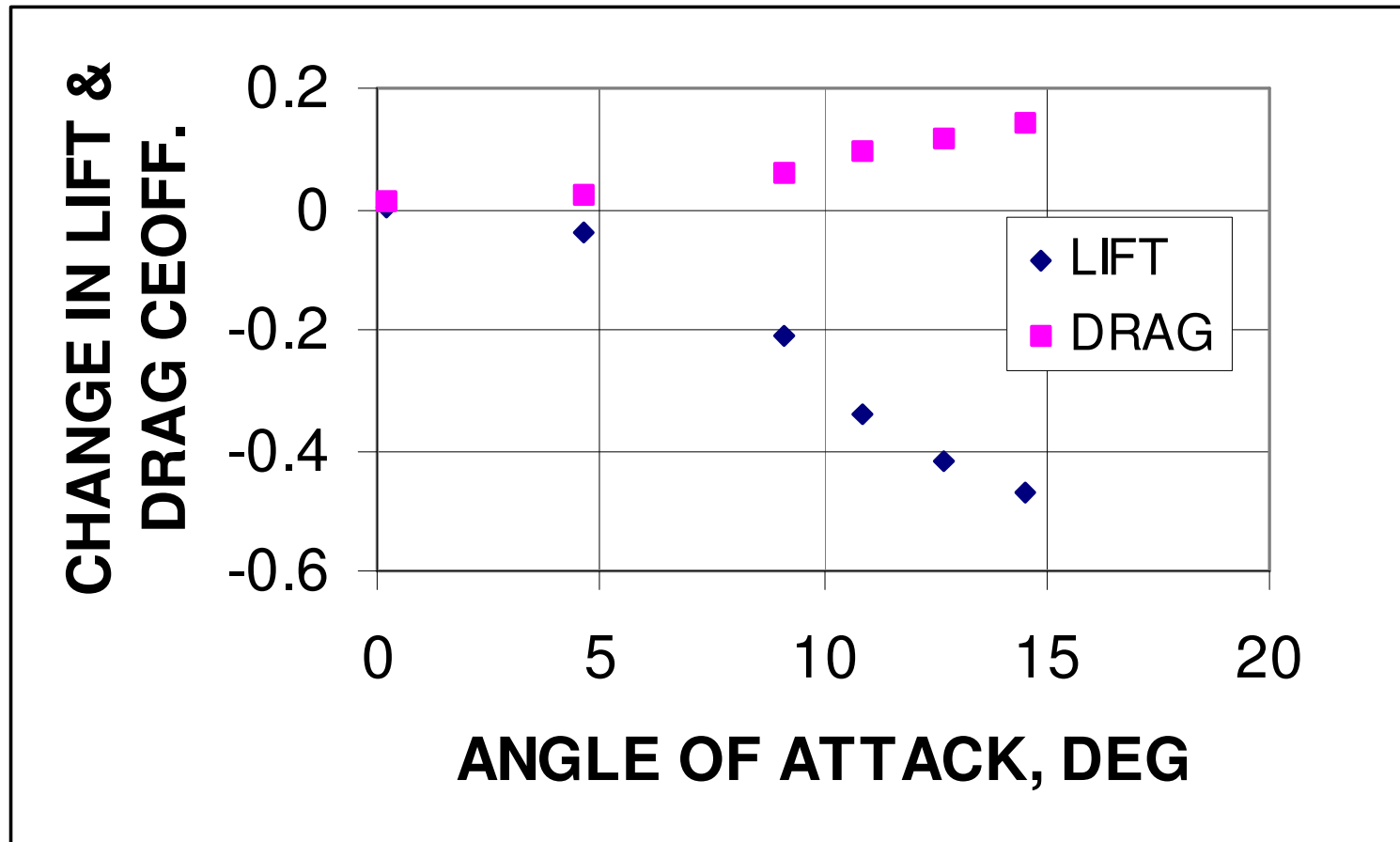
Upper
balance

Lower
balance

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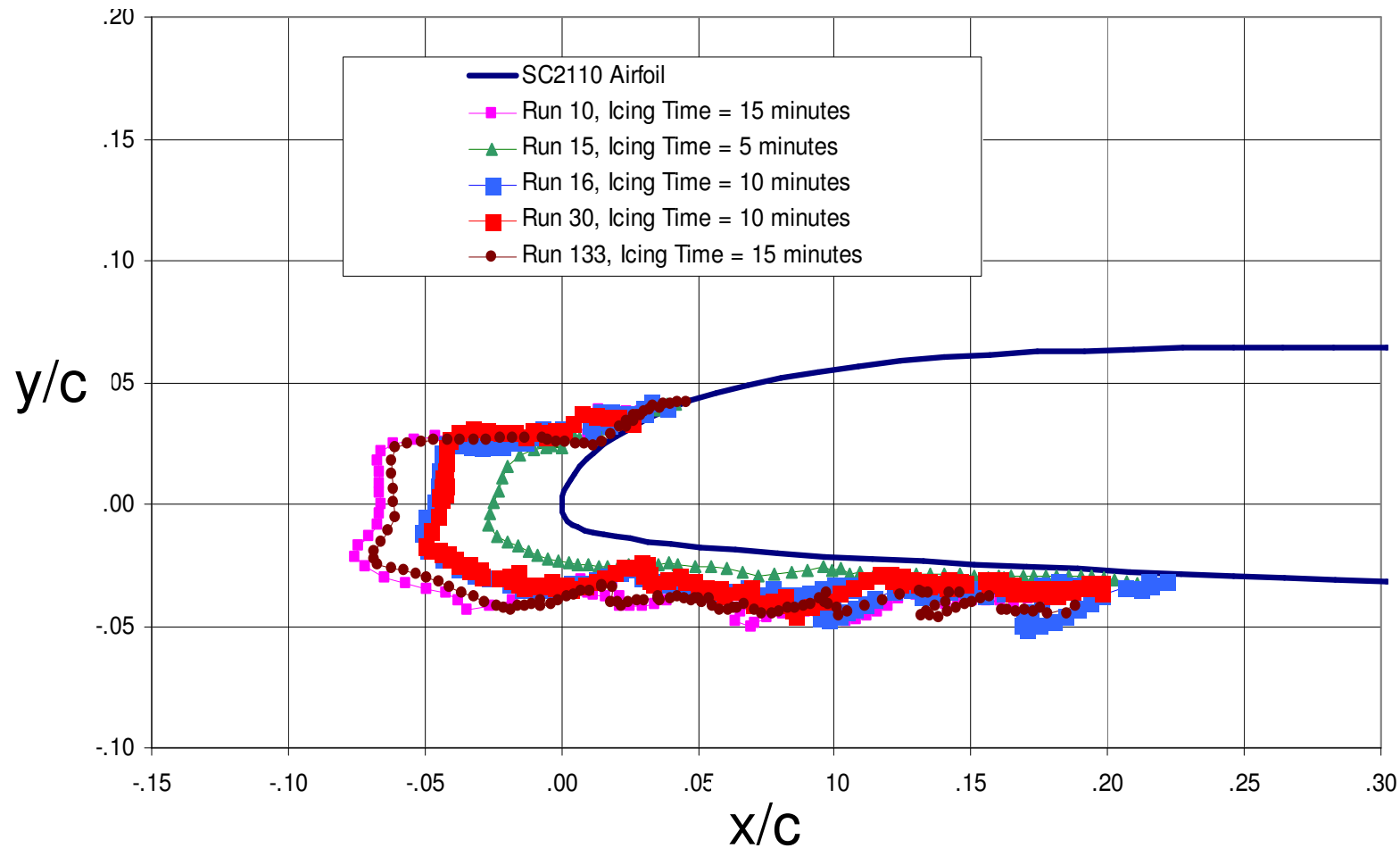


EFFECT OF ICING ON 2D AIRFOIL LIFT & DRAG COEFFICIENTS





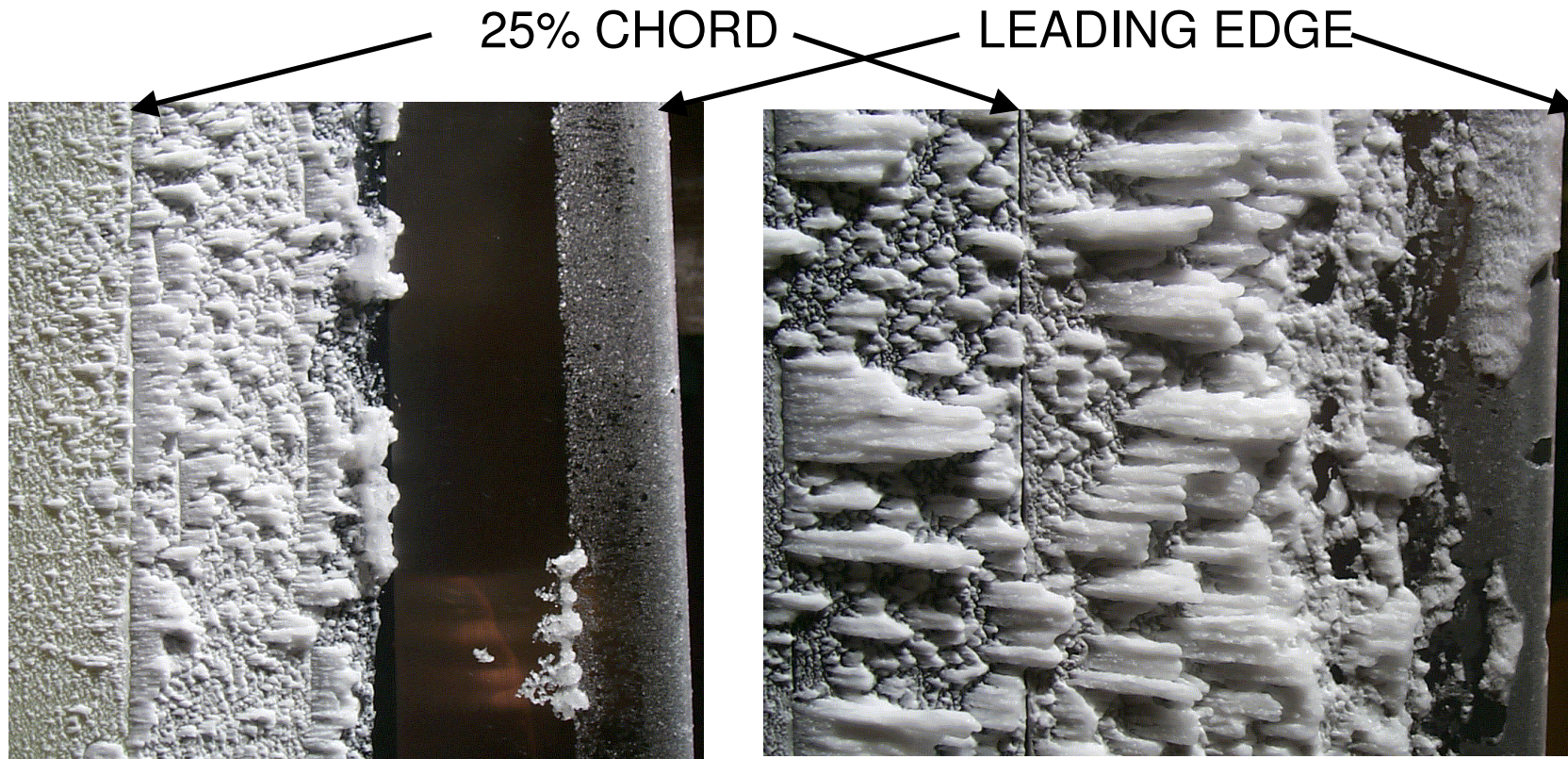
ICE SHAPES AND REPEATABILITY THE IRT



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LOWER SURFACE RESIDUAL ICE



ELECTROTHERMAL

ELECTRO-EXPULSIVE



1989 POWERED FORCE MODEL IN NASA IRT

Test provided ice shape data, torque rise data, and ice shedding data. Data used to correlate and improve the Sikorsky rotor icing code.

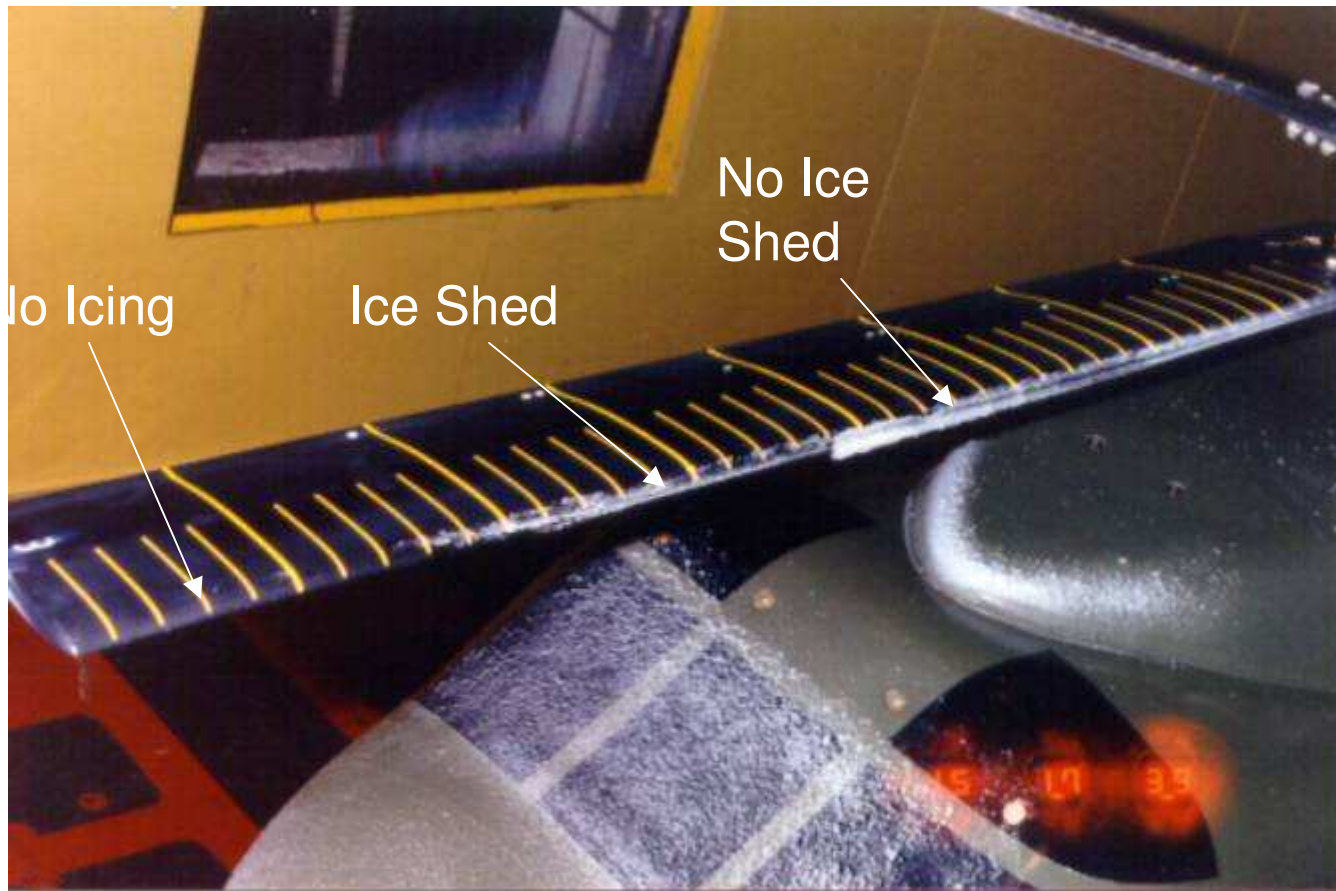
1989 blades had NACA 0012 airfoils, 1993 blades had Sikorsky SC2110 airfoils



Johnson-Williams
Ice Rate meter



POWERED FORCE MODEL IN THE NASA IRT DURING THE 1993 TUNNEL ENTRY



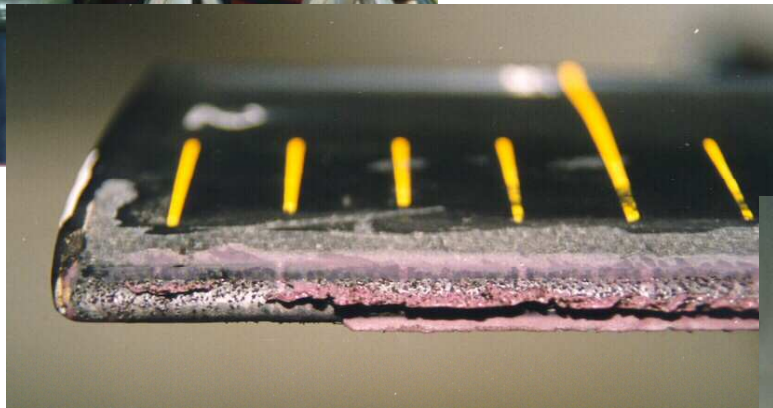
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ICE MOLDING AND SIMULATED ICE

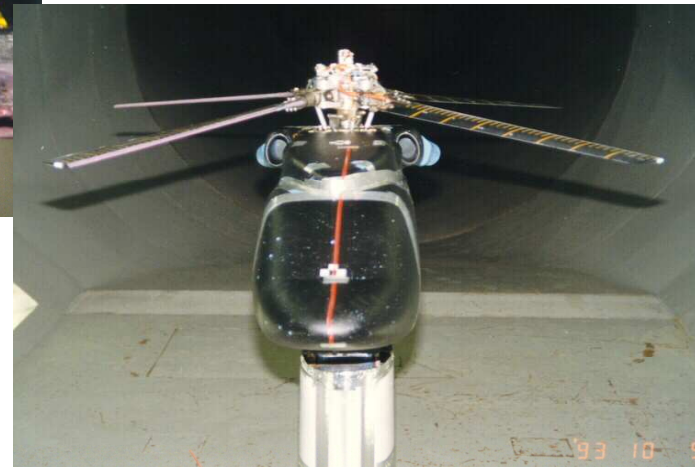


ICE MOLDING IN THE IRT



ICE CAST ON
TO THE BLADE

BLADES WITH CAST ICE
INSTALLED IN A DRY TUNNEL





S-76A IN THE NRC ICING SPRAY RIG

OTTAWA, ONTARIO, CANADA

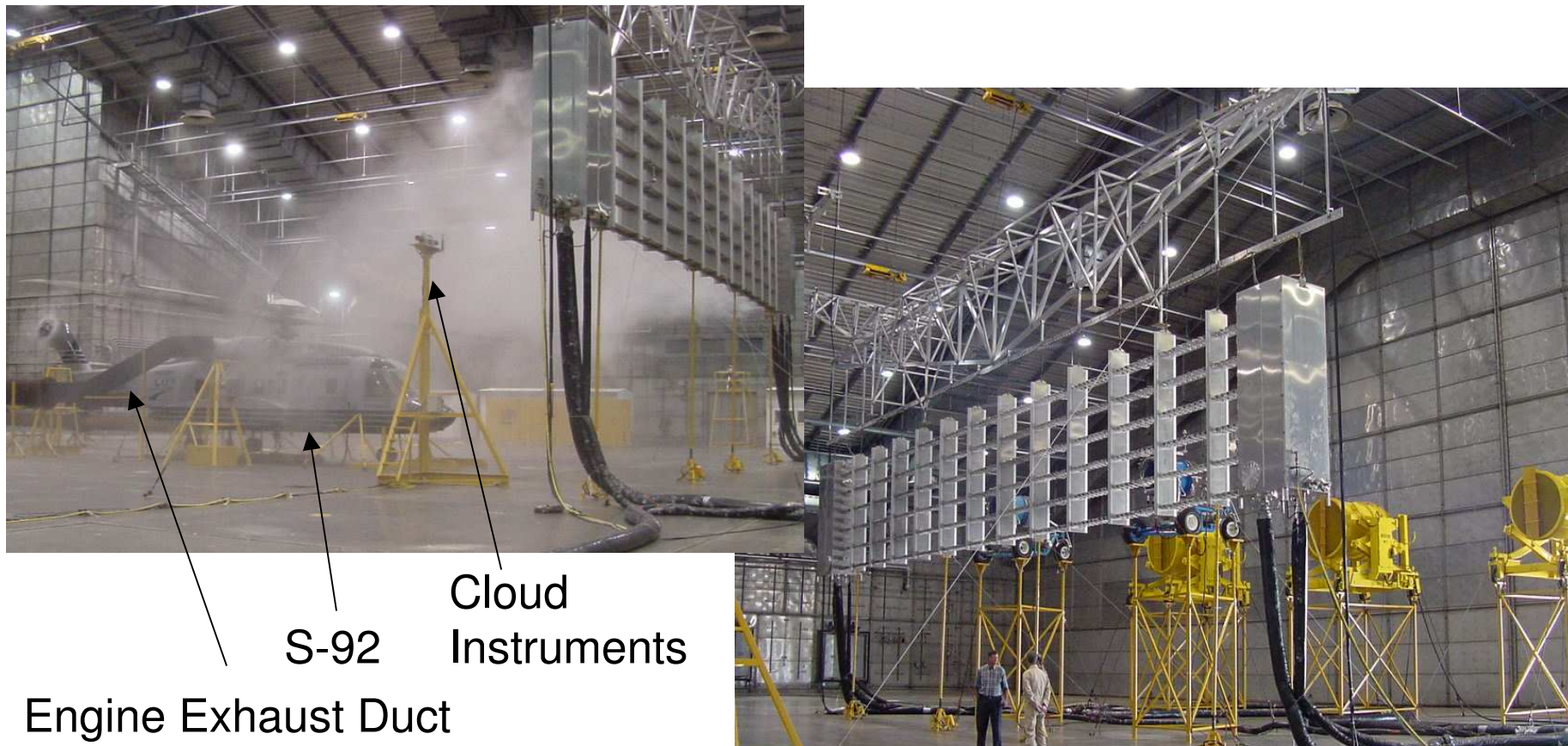


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S-92 IN THE MCKINLEY CLIMATIC LABORATORY

EGLIN AIR FORCE BASE, FLORIDA



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CONCLUSIONS

- Sikorsky Aircraft has conducted considerable rotorcraft icing research and development during the past 58 years.
 - Sikorsky and/or the U.S. Government have flown the UH-60/SH-60, CH-53E, and S-76 in icing conditions.
 - Sikorsky has participated in programs to develop model rotor icing techniques, to gather 2D airfoil icing and deicing data, to use simulated ice and artificial icing techniques, and to develop codes to predict iced-airfoil and iced-rotor performance.
- Sikorsky is using computed ice, simulated ice, artificial icing, and natural icing techniques to certify and qualify rotorcraft for flight in icing conditions at a reduced cost and in less time.